TITLE OF THE INVENTION

FUEL CELL SYSTEM

FIELD OF THE INVENTION

[0001] The present invention is related to a fuel cell system, and more particularly to a fuel cell system capable of supplying fuel gas to a fuel chamber in a short time at a generation startup.

DESCRIPTION OF THE PRIOR ART

[0002] Conventionally, in fuel cell systems using a polymer electrolyte membrane (layer), fuel gas and oxidizing gas are ionized on both sides of the electrolyte layer, and both ionized gases electrochemically react across the electrolyte layer. Therefore, if the fuel gas and the oxidizing gas exist across the electrolyte layer, the electrochemical reaction of both gases continues. In the conventional system, in order to stop the operation of the fuel cell, it adopts a method in which the system stops the supply of both the fuel gas and the oxidizing gas to the fuel cell, and feeds displacement gas such as air or the like to a fuel chamber including a fuel electrode in place of the fuel gas, thereby preventing the electrochemical reaction after stopping the fuel cell.

[0003] Further, at an operation start-up time of the conventional fuel cell system, the displacement gas is discharged outside to start up the reaction by feeding the fuel gas to the fuel chamber.

[0004] In this regard, if a state in which a fuel gas-concentrated region where the fuel gas is more concentrated than other regions and a oxidizing gas-concentrated region where the oxidizing gas is more concentrated than other regions exist in the fuel chamber, namely, under a state the fuel gas and the oxidizing gas are unevenly distributed in the fuel chamber, a portion where the fuel gas is unevenly distributed forms a local cell, and an electric current flows to a portion where the oxidizing gas is unevenly distributed in a reverse

direction of a normal power generation time. Thus, in particular, this makes an oxygen electrode corroded, and there is a problem that this corrosion makes the fuel cell system deteriorate rapidly.

[0005] In the conventional structure, the fuel gas is supplied to the fuel chamber at the operation start-up time at a gas pressure same as the gas pressure of the fuel gas supplied to the fuel chamber during the normal operation time (normal power generation state) of the fuel cell. Thus, when the fuel gas is supplied to the fuel chamber at the operation start-up time, uneven distribution of the fuel and oxidizing gases may happen in the fuel chamber instantaneously. There is a problem that this uneven distribution causes undesirable electrochemical reaction happen, thereby deteriorating the oxygen electrode.

SUMMARY OF THE INVENTION

[0006] It is an object of the present invention to provide a fuel cell system that can inhibit the electrodes from deteriorating.

[0007] In order to achieve the object, the present invention is directed to a fuel cell system. The fuel cell system in one aspect of the present invention comprises:

at least one fuel cell having a fuel chamber including a fuel electrode, an oxygen chamber including an oxygen electrode and an electrolyte layer interposed between the fuel electrode and the oxygen electrode; and

pressure regulating means for regulating a supply pressure of fuel gas to be supplied to the fuel chamber;

wherein the pressure regulating means sets up the supply pressure of the fuel gas at a time when the fuel cell starts up power generation higher than the supply pressure of the fuel gas during a normal power generation state in which the fuel cell is generating electric power.

[0008] In the fuel cell system of the present invention, it is preferred that

the pressure regulating means includes a regulatable pressure valve and control means for controlling the regulatable pressure valve.

[0009] In this invention, it is preferred that the fuel cell system of the present invention further comprises a fuel gas supply line through which the fuel gas flows at the power generation startup time wherein the pressure regulating means includes two regulating valves that respectively provide different supply pressures, a switching valve arranged on the line, and switching means for switching the open and close of the switching valve.

[0010] Further, it is preferred that the normal power generation state of the fuel cell includes a state when the fuel cell is connected to an external load.

[0011] In this invention, it is preferred that the fuel cell system of the present invention further comprises a start switch for turning on and off of the fuel cell system wherein the power generation start-up time of the fuel cell includes a predetermined period of time after the start switch is turned on.

[0012] In this case, it is preferred that the power generation start-up time of the fuel cell includes the case where the start switch is turned on after a lapse of a predetermined period of time after the start switch has been turned off in the normal power generation state.

[0013] In another aspect of the present invention, a fuel cell system comprises:

at least one fuel cell having a fuel chamber including a fuel electrode, an oxygen chamber including an oxygen electrode and an electrolyte layer interposed between the fuel electrode and the oxygen electrode;

a fuel gas concentration sensor for detecting the concentration of a fuel gas discharged from the fuel chamber; and

pressure regulating means for regulating a supply pressure of the fuel gas to be supplied to the fuel chamber based on the detected fuel gas concentration;

wherein the pressure regulating means sets up the supply pressure of the fuel gas at a time when the fuel cell starts up power generation higher than the supply pressure of the fuel gas during a normal power generation state in which the fuel cell is generating electric power.

[0014] In the fuel cell system of the present invention, it is preferred that the pressure regulating means switches the supply pressure of the fuel gas at the start-up time to the supply pressure of the fuel gas at the normal power generation state in the case where the fuel gas concentration detected by the fuel gas concentration sensor is higher than a predetermined fuel gas concentration.

[0015] In this case, it is preferred that the predetermined fuel gas concentration is 95 volume percent.

[0016] In the present invention, it is preferred that the fuel cell system further comprises an oxygen concentration sensor for detecting the concentration of an oxygen gas discharged from the fuel chamber wherein the pressure regulating means switches the supply pressure of the fuel gas at the start-up time to the supply pressure of the fuel gas at the normal power generation state in the case where the fuel gas concentration detected by the fuel gas concentration sensor is higher than a predetermined fuel gas concentration and the oxygen concentration detected by the oxygen concentration sensor is lower than a predetermined oxygen concentration.

[0017] In this case, it is preferred that the predetermined fuel gas concentration is 95 volume percent and the predetermined oxygen gas concentration is 1 volume percent.

[0018] In yet another aspect of the present invention, a fuel cell system comprises:

a start switch for turning on or off of the fuel cell system;

at least one fuel cell having a fuel chamber including a fuel electrode, an

air chamber including an oxygen electrode and an electrolyte layer interposed between the fuel electrode and the oxygen electrode;

a timer for measuring a period of time after the start switch has been turned off; and

pressure regulating means for regulating a supply pressure of fuel gas to be supplied to the fuel chamber;

wherein the pressure regulating means sets up the supply pressure of the fuel gas at a time when the fuel cell starts up power generation higher than the supply pressure of the fuel gas during a normal power generation state in which the fuel cell is generating electric power in the case where the period of time measured by the timer is longer than a predetermined period of time and then thee start switch is turned on.

[0019] The above described and other objects, structures and advantages of the present invention will be apparent when the following description of the preferred embodiment will be considered with reference to the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] Fig. 1 is a block diagram illustrating the fuel cell system of one embodiment according to the present invention.

[0021] Fig. 2 is a whole front view of the fuel cell separator.

[0022] Fig. 3 is a partial cross-section diagram (A-A cross section of Fig. 2) illustrating the fuel cell stack including a fuel cell separator.

[0023] Fig. 4 is a partial cross-section diagram (B-B cross section of Figs. 2 and 3).

[0024] Fig. 5 is a partial cross-section diagram of the fuel cell separator (C-C cross section of Figs. 2 and 3).

[0025] Fig. 6 is a whole back view of the fuel cell separator.

[0026] Fig. 7 is an enlarged cross-session diagram of the unit cell.

[0027] Fig. 8 is a partial plan view of the fuel cell stack.

[0028] Fig. 9 is a whole plan view of the fuel cell stack.

[0029] Fig. 10 is a partial cross-section side view of the fuel cell stack.

[0030] Fig. 11 is a partial cross-section diagram (D-D cross section of Fig. 3) of the fuel cell stack illustrating a vertical section of the hydrogen passage.

[0031] Fig. 12 is a front view of the fuel cell stack.

[0032] Fig. 13 is a back view of the fuel cell stack.

[0033] Fig. 14 is a flowchart illustrating control operation at the start-up time of the fuel cell system in a first embodiment according to the present invention.

[0034] Fig. 15 is a flowchart illustrating control operation at the start-up time of the fuel cell system in a first embodiment according to the present invention.

[0035] Fig. 16 is a flowchart illustrating control operation at the start-up time of the fuel cell system in a second embodiment according to the present invention.

[0036] Fig. 17 is a flowchart illustrating control operation at the start-up time of the fuel cell system in a second embodiment according to the present invention.

[0037] Fig. 18 is block diagram illustrating the fuel cell system of a third embodiment according to the present invention.

[0038] Fig. 19 is block diagram illustrating the fuel cell system of fourth and fifth embodiments according to the present invention.

[0039] Fig. 20 is a flowchart illustrating control operation at the start-up time of the fuel cell system in a fourth embodiment according to the present invention.

[0040] Fig. 21 is a flowchart illustrating control operation at the start-up time of the fuel cell system in a fourth embodiment according to the present invention.

[0041] Fig. 22 is a flowchart illustrating control operation at the start-up time of the fuel cell system in a fifth embodiment according to the present invention.

[0042] Fig. 23 is a flowchart illustrating control operation at the start-up time of the fuel cell system in a fifth embodiment according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0043] The preferred embodiments of a fuel cell system according to the present invention are described below with reference to the appended drawings. In this embodiment, a fuel cell system carried on an electric car is shown. Fig. 1 is a block diagram illustrating the fuel cell system 1 of the present invention. As shown in Fig. 1, the fuel cell system 1 schematically includes a fuel cell stack 100, an air supply system 12, a fuel gas supply system 10 including a plurality of high-pressured hydrogen tanks 11 (hydrogen supply means), and a water supply system 50.

[0044] First, a description will be given for the structure of the fuel cell stack 100. The fuel cell stack is composed of a plurality of fuel cell unit cells 15 and fuel cell separators 13, which are stacked alternately. Fig. 2 is a whole front view of the fuel cell separator 13. Fig. 3 is a partial section view (A-A cross section of Fig. 2) illustrating the fuel cell stack 100 including the fuel cell separator 13. Fig. 4 is a partial section view (B-B cross section of Figs. 2 and 3). Fig. 5 is a partial section view of the fuel cell separator 13 (C-C cross section of Figs. 2 and 3). Fig. 6 is a whole back view of the fuel cell separator 13.

[0045] The separator 13 comprises current collecting members 3, 4 that are connected to the electrodes of the unit cell 15 to take out electric current to the outside, and flame clements 8, 9 externally covered on a peripheral edge portion of each current collecting members 3, 4.

[0046] The current collecting members 3, 4 are made of a metal plate. Such a metal has electric conductivity and corrosion resistance, for example, a metal such as stainless steel, a nickel alloy, a titanium alloy or the like with a corrosion-resistant electric conductivity process applied may be cited.

[0047] The current collecting member 3 abuts on a fuel electrode (anode) of the unit cell 15, while the current collecting member 4 abuts on an oxygen electrode (cathode) of the unit cell 15. The current collecting member 3 is

made with a rectangular plate material, comprising a plurality of columnar protruding portions 32 provided on a surface thereof, and formed by protruding into the fuel electrode side by press process. The columnar protruding portions 32 are vertically and horizontally arranged at even intervals along both a short edge and a long edge of the plate material. Between the columnar protruding portions 32, hydrogen passages 301 are formed by grooves arranged between the columnar protruding portions 32 provided along the long edge (in the lateral direction in Fig. 2), while hydrogen passages 302 are formed by grooves arranged between the columnar protruding portions 32 provided along the short edge (in the longitudinal direction in Fig. 2). The plane including tip portions of the columnar protruding portions 32 serves as an abutting portion 321 to abut on the fuel electrode. A backside of the columnar protruding portion 32 serves as a pit 33. An aperture 35 is formed at both ends of the current collecting member 3, and a hydrogen supply passage is composed of the aperture 35 when the separators 13 are stacked.

[0048] The current collecting member 4 is made of a rectangular plate material, comprising a plurality of protruding portions 42 arranged on a surface thereof and formed by protruding into the fuel electrode side by press process. The protruding portions 42 are linearly arranged at even intervals parallel to a short edge of the plate material. Grooves are formed between the protruding portions 42, and they constitute air passages 40. The plane including tip portions of the protruding portions 42 serves as an abutting portion 421 to abut on the oxygen electrode. A backside of the protruding portion 42 serves as a canaliform hollow portion that forms a cooling passage 41. The air passage 40 and the cooling passage 41 extend to the end portion of the plate material, and the both ends thereof have an opening portion that opens at the end portion of the plate material. An aperture 48 is formed at both ends of the current collecting member 4, and a hydrogen supply passage is composed of the aperture 48 when the separators 13 are stacked.

[0049] The current collecting members 3, 4, having above structure are stacked and fixed so that the columnar protruding portions 32 and the

protruding portions 42 are arranged outside of the stack. In this case, the backside surfaces 34 of the hydrogen passages 301, 302 abut on the backside surface 403 of the air passage 40, which makes it possible to become a conductive state. Further, as shown in Fig. 4, the cooling passage 41 is formed by stacking the current collecting members 3, 4, and the pit 33 forms a part of the cooling passage 41. On the other hand, as shown in Figs. 3 and 5, the air passage 40 is formed as a tubular passage by being stacked on the unit cell 15 and blocking the opening portion 400 of the groove. The oxygen electrode forms a part of the inner wall of the air passage 40. Oxygen and water are supplied to the oxygen electrode of the unit cell 15 from the air passage 40.

[0050] The opening portion at one end of the air passage 40 forms an inflow port 43 at which the air and water inflow, while the opening portion at the other end of the air passage 40 forms an outflow port 44 at which the air and water outflow. The opening portion at one end of the cooling passage 41 forms an inflow release port 45 at which the air and water inflow, while the opening portion at the other end of the cooling passage 41 forms an outflow release port 46 at which the air and water outflow. In the structure mentioned above, the air passage 40 and the cooling passage 41 are arranged parallel alternately, and they are adjoining each other across a sidewall 47. In this way, the inflow ports 43 and the inflow release ports 45 are also arranged alternately. Since the air and water flow along the sidewall 47, the sidewalls 47 function as cooling fins.

[0051] By arranging the air passage 40 and the cooling passage 41 parallel and alternately, it becomes possible to improve the cooling efficiency of the fuel cell, allowing even cooling of the fuel cell.

[0052] The flame elements 8, 9 are respectively stacked on the current collecting members 3, 4. As shown in Fig. 2, the flame element 8 stacked on the current collecting member 3 has the same size as the current collecting member 3, and a window 81 for storing the columnar protruding portion 32 is formed at the center thereof. Further, an aperture 83 is formed at the position

corresponding to the position of the aperture 35 of the current collecting member 3 adjacent to both ends of the flame element 8. A concavity is formed in the plane abutting on the current collecting member 3 between the aperture 83 and the window 81 to provide a hydrogen flow passage 84. In the plane opposite to the plane abutting on the current collecting member 3, the concave portion in which the profile thereof is formed along the window 81 is formed to provide a storage portion 82 for storing the unit cell 15. A fuel chamber is defined by the surface of the fuel electrode on the unit cell 15 accommodated in the storage portion 82, the hydrogen passages 301, 302, and the window 81.

[0053] The flame element 9 stacked on the current collecting member 4 has the same size of the flame element 8, and a window 91 for storing the protruding portion 42 is formed at the center thereof. Further, an aperture 93 is formed at the position corresponding to the position of the aperture 83 of the flame element 8 adjacent to both ends of the flame element 9. On the surface on which the current collecting member 4 of the flame element 8 is stacked, a groove is formed along a pair of facing long edges of the flame element 8, and air flow passages 94, 95 are formed by stacking the current collecting members 3, 4. One end of the air flow passage 94 is connected to an opening 941 formed on an end face on the long edge side of the flame element 8, while the other end thereof is connected to the inflow port 43 of the air passage 40 and to the inflow release port 45 of the cooling passage 41.

[0054] In the air flow passage 94 located on the upstream side, an inner wall of the end portion thereof forms a tapered surface 942 so that the cross-sectional area decreases gradually from an opening 941 side toward the air passage 40 side, allowing water to be sprayed into the air flow passage 94 from an air manifold 54 (will be described later). On the other hand, one end of an air stream passage 95 located on the downstream side is connected to the outflow port 44 of the air passage 40 and the inflow release port 45 of the cooling passage 41, while the other end is connected to an opening 951 formed on the end face on the long edge side of the flame element 8. In the air flow passage 95, an inner wall at the end portion forms a tapered surface 952 so that the

cross-sectional area decreases gradually from the opening 951 side toward the air passage 40 side. Even though the fuel cell stack 100 is inclined, the discharge of the water is maintained by the tapered surface 952.

[0055] Further, in the opposite plane of the fame element 9 against the surface abutting on the current collecting member 4, the concave portion in which the profile thereof is formed along the window 91 is formed to provide a storage portion 92 for storing the unit cell 15.

[0056] Fig. 7 is an enlarged cross-session diagram of the unit cell 15. Unit cell 15 is equipped with a solid polymer electrolyte membrane 15a, and an oxygen electrode 15b, and a fuel cell electrode 15c respectively stacked at both sides of the solid polymer electrolyte membrane 15a. The solid polymer electrolyte membrane 15a has a size corresponding to the size of the storage portions 82, 92, and the oxygen electrode 15b and the fuel electrode 15c each has a size corresponding to the size of the windows 81, 91. Since the thickness of the unit cell 15 is extremely thinner than that of any one of the flame elements 8, 9 and the current collecting members 3, 4, it is shown in the drawings as one unit.

[0057] Hydrophilic process is applied to inner walls of the air passage 40 and the cooling passage 41. The surface treatment is applied to the inner walls so that contact angle between the surface of the inner wall and the water is less than 40 degrees, preferably less than 30 degrees. The method of applying hydrophilic agent to the surface is adopted as this treatment. As the agent to be applied, for example, polyacrylamide, polyurethane resin, titanium oxide (titanium dioxide), or the like may be cited.

[0058] The separator 13 is constructed so that the current collecting members 3, 4 are held by the flame elements 8, 9 having above-mentioned structure. The fuel cell stack 100 is constructed by stacking the separators 13 and the unit cells 15 alternately. Fig. 8 is a partial plan view of the fuel cell stack 100. A plurality of the inflow ports 43 and the inflow release ports 45 are

opened alternately on the top surface of the fuel cell stack 100. As described later, the air from the air manifold 54 and the water sprayed from a plurality of nozzles 55 simultaneously flow into the introducing ports 43 and the inflow release ports 45. In this case, the sidewalls 47 function as cooling fins.

[0059] The air and the water that respectively flow via the introducing ports 43 and the inflow release ports 45 cool down the current collecting members 3, 4 in the cooling passage 41 by latent heat cooling.

[0060] Fig. 9 is a whole plan view of the fuel cell stack 100. Unit 130 is formed by stacking a predetermined number of the fuel cell separators 13 having the structure mentioned above. The fuel cell stack 100 is constructed by stacking a plurality of units 130. A separator 14 lies between the units 130, 130, and is constructed by putting a shield plate 16 between the current collecting members 3, 4. The shield plate 16 comprises an aperture 161a or 161b having a sectional shape same as a hydrogen passage 17a or 17b in the position corresponding to that of either the hydrogen passage 17a or the hydrogen passage 17b. Since the shield plate 16 has electric conductivity, it does not prevent electric current from flowing in the fuel stack 100.

[0061] On the other hand, in the case where the shield plate 16 has the aperture 161a, the shield plate 16 prevents the hydrogen gas from flowing in the hydrogen passage 17b. In the case where the shield plate 16 has the aperture 161b, the shield plate 16 prevents the hydrogen gas from flowing in the hydrogen passage 17a. The shield plates 16 are alternately arranged so that the shield plate 16 having the aperture 161b, the shield plate 16 having the aperture 161a ... are sequentially positioned from the inflow side of the hydrogen gas to the outflow side of the hydrogen gas. In this way, the supplied hydrogen gas flows into each fuel chamber 30 in every unit 130 by alternately shielding either the hydrogen passage 17a or 17b every unit 130. More specifically, as shown in Fig. 9, the hydrogen gas flows from the hydrogen passage 17a toward the hydrogen passage 17b in the first unit 130, in the second unit 130 the gas flows from the hydrogen passage 17b toward the

hydrogen passage 17a, and in the third unit 130 the gas flows from the hydrogen passage 17a toward the hydrogen passage 17b. Thus, the hydrogen gas flows while its flow directions are alternated.

[0062] Namely, the fuel cell stack 100 includes units 130 in which the unit cells 15 and the separators 13 are stacked, and a pair of hydrogen passages 17a, 17b that respectively communicate with each fuel chamber 30, which are formed along a stacked direction of the separators 13 in the unit 130 and positioned at both sides of the fuel chamber 30, and the fuel cell stack 100 is constructed by stacking the units 130. Further, between the abutting units 130, the fuel cell stack 100 includes communicating portions 161a (or 161b) for communicating between the hydrogen passages 17a, 17a (or 17b, 17b), and a blocking portion (the shield plate 16) for restricting the flow of the hydrogen gas between the other hydrogen passages 17b, 17b (or 17a, 17a). The communicating portions and the blocking portions are alternately arranged so that either the one hydrogen passages 17a, 17a (or 17b, 17b) or the other hydrogen passages 17b, 17b (or 17a, 17a) alternately face in the direction of the stacked direction of the stacked units 130. In this case, the hydrogen gas flows in the fuel chambers 30 of the units while its flow direction is alternately changed.

[0063] In this way, since the fuel cell stack 100 is divided into the plurality of units 130, and makes the hydrogen gas flow in every unit 130, it is possible to prevent the hydrogen gas flow rate from making a difference in each of the units 130. Further, in each unit 130, it is also possible to prevent the hydrogen gas flow rate making a difference in each of the fuel chambers 30 constructed by stacking the separators 13 and the unit cells 15. Furthermore, since the hydrogen gas supplied in the fuel cell stack 100 repeatedly flows in the unit 130, the hydrogen gas has many opportunities to come into contact with the fuel electrode of the fuel chamber 30, thereby making the reaction efficiency between the hydrogen and oxygen gases improve. Since the total volume of the fuel chamber 30 belonging to one unit 130 is secured to such an extent that a large amount of hydrogen gas can flow, the hydrogen gas does not grow

stagnant in the fuel chamber 30 of the unit 130 and can flow from the fuel chamber 30 to the outside of the unit 130 (namely, the outside of the fuel cell stack 100) in a short time in the case where the speed of supply of the hydrogen is increased (namely, the flow rate of the hydrogen is increased). Thus, this makes the rate of replacement (rate of substitution) increase (namely, this shortens the time required to replace the substituted gas by the hydrogen), and it is possible to further shorten the time when the substituted gas and the hydrogen are unevenly distributed, and this makes it possible to prevent deterioration of the electrodes. Further, increasing the flow rate of the hydrogen during a normal power generation state makes the discharge of generated water easy, and this makes it possible to prevent power deterioration by the clogged drain of the fuel cell.

[0064] The number of the fuel cell separators 13 constituting the unit 130 is determined so that the cross-sectional area of the hydrogen passage 302 in each of the separators 13 is about the same as the cross-sectional area of the hydrogen passages 17a, 17b. The cross-sectional area of the hydrogen passage 302 is the area in the position in which the area of the surface perpendicular to the flow line of the hydrogen gas that flows in the fuel chamber 30 is minimized, namely, total area of "a" portions in Fig. 10 (the total cross-sectional area of the hydrogen passage 302 in the separator 13 constituting the unit 130), or the total cross-sectional area of the hydrogen flow passage 84 (namely, the area of "b" portion circled by the heavy line in Fig. 11). By having the structure mentioned above, since the cross-sectional area of the flow passage of hydrogen gas that flows in the fuel cell stack 100 does not fluctuate widely while the gas flows in the fuel cell stack 100 (namely, from the inflow to the outflow), it is possible to distribute the gas evenly in the fuel chamber 30 of each of the separators 13 constituting the unit 130.

[0065] Therefore, the substituted gas (namely, air) filled in the fuel cell stack 100 can be discharged efficiently when the fuel gas supplies at the power generation start-up time, thereby replacing the substituted gas by the hydrogen gas more evenly and rapidly.

[0066] Fig. 12 is a front view of the fuel cell stack 100. An introducing guide passage 18a is provided on the hydrogen inflow portion of the hydrogen passage 17a as a current means. The introducing guide passage 18a includes a gas introducing port 181a having the same cross-sectional shape as a hydrogen introducing passage 202 (see Fig. 1), and a gas discharging port 182a having the same cross-sectional shape as the hydrogen passage 17a. The width of a passage 183a between the gas introducing port 181a and the gas discharging port 182a is increased gradually, and guides the gas stream so that the distribution of the gas flow rate in the cross-sectional surface of the hydrogen passage 17a may become uniform (even). Further, a plurality of current plates 184a are provided on the passage 183a, and are constructed so as to guide the hydrogen gas while controlling the pressure loss of the gas stream.

[0067] Fig. 13 is a back view of the fuel cell stack 100. A discharging guide passage 18b is provided on the hydrogen gas outflow portion of the fuel cell stack 100. The discharging guide passage 18b includes a gas introducing port 181b having the same cross-sectional shape as the hydrogen passage 17a, and a gas discharging port 182b having the same cross-sectional shape as a hydrogen outflow line 203 (see Fig. 1). The width of a passage 183b between the gas introducing port 181b and the gas discharging port 182b is decreased gradually. Further, a plurality of current plates 184b are provided on the passage 183b, and are constructed so as to guide the hydrogen gas while controlling the pressure loss of the gas stream.

[0068] According to the structure of the fuel cell stack 100 mentioned above, the hydrogen gas flowing into the fuel cell stack 100 is prevented from pressure loss, and is evenly (uniformly) supplied to the fuel chamber 30 of each of the fuel cell separators 13.

[0069] Next, a description will be given for other elements shown in Fig. 1. An air supply system 12 supplies atmospheric air to the air passage 40 and the cooling passage 41 via the opening 941 of the fuel cell stack 100, and discharges

the air discharged from the fuel cell stack 100 through a condenser 51. An air fan 122 is provided on an air supply line 123 as suction means, and sends the air to the air manifold 54 from the atmospheric air. The air flows into the air passage 40 of the fuel cell stack 100 from the air manifold 54 to supply oxygen to the oxygen electrode (namely, the current collecting member 3). The moisture of the air discharged from the fuel cell stack 100 is condensed and recovered in the condenser 51, and then the dry air is discharged. The temperature of the air discharged from the fuel cell stack 100 is monitored by a discharge-gas temperature sensor S1. Electrical-potential detection sensors S2 are provided on the fuel cell stack 100 to measure the local electrical potential of each of the unit cells 15 constructing the fuel cell stack 100.

[0070] In this embodiment, the nozzles 55 are provided on the air manifold 54, and the water is sprayed from the nozzles 55 into the air in liquid state to be mixed with the air. Most of the water is recovered by a container (not shown in the drawings) provided on the lower side of the fuel cell stack 100 while remaining in the liquid state.

[0071] The fuel gas supply system 10 sends the hydrogen gas released from the high-pressured hydrogen tanks 11 to the hydrogen passage 17a of the fuel cell stack 10 via the hydrogen conducting line 201 and the hydrogen inflow line 202. On the hydrogen conducting line 201, a hydrogen primary pressure sensor S3, a hydrogen primary pressure regulating valve 21, a hydrogen base electromagnetic valve 22, a hydrogen secondary pressure regulatable-pressure valve 23, a hydrogen supply electromagnetic valve 24, and a hydrogen secondary pressure sensor S4, are provided in this order from the high-pressured hydrogen tanks 11 side toward the fuel cell stack 100. The hydrogen pressure of the high-pressured hydrogen tanks 11 is monitored by the hydrogen primary pressure sensor S3. In this case, the hydrogen secondary pressure regulatable-pressure valve 23 and a control section (will be described later) for controlling the hydrogen secondary pressure (i.e., controlling the set value of the regulatable-pressure valve 23) constitute pressure regulating means for regulating a supply pressure of the fuel gas (hydrogen gas) to be

supplied to the fuel chamber 30.

[0072] The conducted hydrogen is regulated at a pressure adapted to supply to the fuel cell stack 100 by the hydrogen primary pressure regulating valve 21. The supply of the hydrogen to the fuel cell stack 100 is electrically controlled by open/close of the hydrogen base electromagnetic valve 22. In the case where the supply of the hydrogen gas is not carried out, the supply of the hydrogen gas is prevented by closing the electromagnetic valve 22. Further, the hydrogen gas pressure just before it is supplied to the fuel cell stack 100 is monitored by the hydrogen secondary pressure sensor S4.

[0073] On end of the hydrogen inflow line 202 is connected to the hydrogen conducting line 201, while the other end is connected to the hydrogen passage 17a of the fuel cell stack 100.

[0074] In the fuel cell stack 100, as shown in Fig. 3, the hydrogen gas flows from the hydrogen passage 17a to the hydrogen flow passage 84a, and then flows from the hydrogen flow passage 84a to the hydrogen passages 301, 302. The hydrogen gas is supplied to the fuel electrode on the hydrogen passages 301, 302, and then the remaining hydrogen gas flows from the hydrogen flow passage 84b to the hydrogen passage 17b.

[0075] The hydrogen gas discharged from the hydrogen passage 17b of the fuel cell stack 100 is sent to the hydrogen outflow line 203 on the fuel gas supply system 10. An oxygen concentration sensor S5, a hydrogen concentration sensor S6 and a hydrogen pump 25 are provided on the hydrogen outflow line 203. The hydrogen pump 25 introduces the hydrogen gas discharged from the fuel cell stack 100 into the check valves 26, 29. Both one end of a hydrogen discharge line 204 and one end of a hydrogen return line 205 are connected to the downstream side of the hydrogen pump 25. The other end of the hydrogen return line 205 is connected to the hydrogen inflow line 202, whereby a hydrogen circular line is formed from the hydrogen inflow line 202, the hydrogen outflow line 203 and the hydrogen return line 205. The check valve

29 is provided on the hydrogen return line 205, and the hydrogen gas supplied from the high-pressured hydrogen tanks 11 cannot be discharged to the hydrogen discharge line directly. The check valve 26, a hydrogen discharge electromagnetic valve 27a, and a silencer 28a are provided on the hydrogen discharge line 204 in this order.

[0076] The oxygen concentration sensor S5 detects the oxygen concentration of the gas discharged from the fuel cell stack 100, while the hydrogen concentration sensor S6 detects the hydrogen concentration of the gas discharged from the fuel cell stack 100.

[0077] In the water supply system 50, the water in a water tank 53 is pressure-fed (put pressure and supplied) to the nozzles 55 provided on the air manifold 54 through a water supply line 56 by a water supply pump 61, and then the supplied water is sprayed from the nozzles 55 into the air manifold 54 continuously or intermittently. This water is sent to the air passage 40 and the cooling passage 41 via the opening 941 of the fuel cell stack 100. Since the latent heat is preferentially drawn from the water in this place, this makes it possible to prevent the moisture of the solid polymer electrolyte membrane 15a of the oxygen electrode 15b side from evaporating. Therefore, the electrolyte membrane 15a of the oxygen electrode 15b side can be maintained in an even wet condition constantly due to the generated water without drying out the electrolyte membrane 15a at the oxygen electrode 15b side. Further, the heat of the oxygen electrode 15b itself is drawn due to the water supplied to the surface of the oxygen electrode 15b and the water flowing into the cooling passage 41 to cool it down. Thus, the temperature in the fuel cell stack 100 can be controlled.

[0078] According to the structure mentioned above, it is possible to cool down the fuel cell stack 100 adequately without an additional cooling water system to cool down the fuel cell stack 100. In this regard, it is possible to maintain the temperature of the fuel cell stack 100 around a desired temperature by controlling the output of the water supply pump 61 in response

to the temperature of the discharged air detected by the discharge-gas temperature sensor S1.

[0079] The water in the water tank 53 is supplied to the surface of the oxygen electrode 15b from the nozzles 55 provided on the air manifold 54, and then the supplied water is recovered by the condenser 51 and sent to the water tank 53 by a water collection pump 62 together with the water stored in the container (not shown in the drawings). A check valve 52 is provided between the water collection pump 62 and the water tank 53 to prevent the water in the water tank 53 from flowing to the water collection pump 62. The water level in the water tank 53 is detected by the water level sensor S7.

[0080] Further, the fuel cell system 1 includes a start switch, namely, an ignition key for starting up and stopping the system 1 (not shown in the drawings), namely, for turning on or off of the fuel cell system 1. The fuel cell system 1 is connected to an external load (not shown in the drawings) in the normal power generating state (in the normal operation time).

[0081] In the structure mentioned above, in the normal operation state (i.e., the normal power generation state) in which the fuel cell system 1 outputs the electric power, the air is supplied from the air fan 122 to the fuel cell stack 100, and simultaneously the hydrogen gas is supplied from the fuel supply system 10 to the fuel cell stack 100. The redox reaction for power generation is continued in the fuel cell stack 100, and this reaction generates the electric power and the water. Such the reaction can be maintained by supplying the air and the hydrogen gas to the oxygen electrode 15b and the fuel electrode 15c, respectively. In view of the efficiency of consumption of the hydrogen gas, the necessary concentration of hydrogen gas at which the redox reaction can be generated in the unit cell 15 is supplied to the fuel cell stack 100, and the supply pressure at the normal operation time is set within the range in which the required reaction can be maintained and the waste of the hydrogen gas can be eliminated. In the case where the supply pressure at the normal operation time is higher than necessary, there occurs a glut that results in the discharge of most of the

non-reacted hydrogen gas therefore wasting fuel (i.e., the wasting of the hydrogen gas). Based on this standpoint, the supply-gas pressure of the hydrogen gas at the normal operation time is set at 0.1 MPa, for example. On the other hand, due to the discharge of the substituted gas and prevention of uneven distribution of the gases, the supply pressure of the hydrogen gas at a power generation start-up time is set at a pressure value (for example, 0.2 MPa) higher than the gas pressure at the normal operation state, and the supply time of the hydrogen gas is also set at the higher pressure value in a very short time.

[0082] In this embodiment of the present invention, "a normal operation time (normal power generation state)" includes "a time when the fuel cell system 1 is connected to the external load," that is, a state where the fuel cell system 1 is generating electrical power, and "a power generation start-up time" includes "a period of time from the time when the fuel cell system 1 is started up by the ignition key to the time when the fuel cell system 1 is connected to the external load." Further, "the start-up time" also includes "the case (state) where the start switch is turned on after a lapse of a predetermined period of time after the start switch has been turned off in the normal power generation state," and "the normal operation time (normal power generation state)" also includes "a state when the fuel cell system 1 is being connected to the external load after a lapse of the predetermined period of time."

[0083] Each element of the fuel cell system 1 described above is controlled by a control section (not shown in the drawings). The values detected by the sensors S1-S7 are supplied to the control section. More specifically, the control section controls the amount of water supplied by the water supply pump 61, on/off operation of the water collection pump 62, on/off operation of the air fan 122, and on/off operation of the hydrogen pump 25. Further, the control section also controls open/close operation of the hydrogen base electromagnetic valve 22, open/close operation of the hydrogen supply electromagnetic valve 24, open/close operation of the hydrogen discharge electromagnetic valve 27a, and a set pressure of the hydrogen secondary-pressure regulatable pressure valve 23. In this case, the control section may include a timer for measuring a

predetermined time, or the control section may be connected to the timer. The timer measures a period of time after the ignition key (start switch) has been turned off in the normal power generation state. In this regard, "a power generation start-up time" means "a predetermined period of time in the case where the start switch is turned on after a lapse of a given period of time (for example, six hours) after the start switch has been turned off in the normal power generation state. Namely, before the lapse of the predetermined period of time, this start-up operation of the present invention (will be described later) may not be carried out.

[0084] The fuel cell system 1 having the structure described above carries out the following operation at the start-up time. Figs. 14 and 15 are a flowchart illustrating control operation of the fuel supply system 10 at the start-up time of the fuel cell system1 in a first embodiment according to the present invention.

[0085] When it is confirmed that a start-up operation such as the ignition key is turned ON and the like is carried out (Step S101), all of the sensors of the fuel cell system 1 are switched (turned) ON (Step S103). The turn-ON operation of the sensors allows the detection values of the whole system to be obtained. It is judged whether or not a hydrogen primary pressure is more than a predetermined set value based on the detection value supplied from the hydrogen primary pressure sensor S3 (Step S105). This predetermined set value may be set at 1 MPa, for example. In the case where the primary pressure is less than the set value, the start-up operation is suspended (stopped) (Step S109) because it means to be short (lack) of the amount of hydrogen in the high-pressured hydrogen tanks 11. On the other hand, in the case where it is judged that the primary pressure is more than the set value, it is judged whether or not a water level in the water tank 53 is higher than a predetermined level based on the detection value supplied from the water level sensor S7 (Step S107). In the case where it is judged that the water level is less than the predetermined level, the start-up operation is suspended (Step S109) because it is impossible to cool down the fuel cell stack 100 adequately.

[0086] In the case where it is judged that the level in the water tank 53 is higher than the predetermined level, the water collection pump 62 is switched ON to start to collect water (Step S111). Further, the water supply pump 61 is switched ON to spray water from the nozzles 55 of the air manifold 54 into the fuel cell stack 100 (Step S113). At the same time, the hydrogen base electromagnetic valve is opened. Next, the air supply fan 122 is driven (switched ON) to supply air into the fuel cell stack 100. Thus, it starts to supply air and water to the oxygen electrode 15b in the fuel cell stack 100.

[0087] Next, in order to supply hydrogen gas into the fuel cell stack 100, a discharge operation to discharge the residual oxygen gas (i.e., air) in the fuel chamber of the fuel cell stack 100 is started. Namely, the hydrogen discharge electromagnetic valve 27a is opened (Step S117), and the hydrogen pump 25 is driven (switched ON) (Step S119). Thus, a suction pressure to suck the hydrogen gas from the fuel chamber 30 of the fuel cell stack 100 is generated, thereby making the inside of the fuel chamber 30 a negative pressure.

[0088] Next, a set pressure of the hydrogen secondary pressure regulatable pressure valve (variable regulator) 23 is set (established) at 0.2 MPa (Step S121), and the hydrogen supply electromagnetic valve 24 is opened (Step S123). Thus, the hydrogen gas having the pressure of 0.2 MPa is supplied into the fuel chamber 30 where the negative pressure is established. At the same time, the residual gas that remains in the fuel chamber 30 before the start-up operation is pushed out to the outside of the fuel chamber 30 by the supplied hydrogen gas, and sucked (discharged) by the hydrogen pump 25. This state is maintained for 0.5 seconds (Step S125), and after 0.5 seconds elapsed, it is judged whether or not the hydrogen concentration of the discharged gas is more than 95 volume percent (vol. %) based on the detection value when the hydrogen concentration sensor S6 detects the discharged gas from the fuel cell stack 100. In the case where the hydrogen concentration does not reach 95 volume percent within 0.5 seconds, an alarm (not shown in the drawings) is switched ON because there is possibility to deteriorate the electrodes, and then a program of the start-up

operation proceeds to Step S135. On the other hand, in the case where the hydrogen concentration is more than 95 volume percent, it is possible to estimate that the fuel chamber 30 is permeated with the hydrogen gas without uneven distribution of gases, or that there is very few oxygen gas in the fuel chamber 30 enough for occurrence of the local electric current.

[0089] Next, it is judged whether or not the oxygen concentration of the discharged gas is less than 1 volume percent based on the detection value of the oxygen concentration sensor S5 (Step S129). In the case where it is judged that the oxygen concentration is more than 1 volume percent, the alarm is switched ON (Step S133), and then the program proceeds to Step S135. On the other hand, in the case where the oxygen concentration is less than 1 volume percent, it is possible to estimate that the oxygen gas hardly remains in the fuel chamber 30, or that there is very little oxygen gas in the fuel chamber 30 enough for occurrence of the local electric current.

[0090] In the case where it is judged that the oxygen concentration is less than 1 volume percent, it is judged whether or not the local electrical potential of each electrode in the unit cells 15 is less than 1.1 Volts (V) based on the detection values of the electrical-potential detection sensors S2 (Step S131). In the case where there is an electrode having more than 1.1 V, the alarm is switched ON (Step S133), and then the program proceeds to Step S135. Since it is difficult to determine an extent of the gas uneven distribution in each of the fuel chambers 30 only by detecting the hydrogen concentration and the oxygen concentration of the discharged gas, the system is constituted so as to be able to judge possibility of the gas uneven distribution by detecting the local electrical potential of each electrode in the unit cells 15.

[0091] In the case where it is judged that all of the local potentials are less than 1.1 V at Step S131, it means that the oxygen gas (air) in each of the fuel chambers 30 is substantially evenly substituted with the hydrogen gas. Therefore, the set pressure of the hydrogen secondary pressure regulatable pressure valve (variable regulator) 23 is set (established) at 0.1 MPa (Step

S135), and the hydrogen discharge electromagnetic valve 27a is closed (Step S137). Then, this start-up operation program is terminated and the system proceeds to a normal operation (power generation) routine (this routine is not shown in the flowchart.).

[0092] Figs. 16 and 17 are a flowchart illustrating control operation at the start-up time of the fuel cell system in a second embodiment according to the present invention. Since the operations at Steps S201-S223 are same as those at Steps S101-S123 of the first embodiment shown in Fig. 14, a description of these steps is omitted.

[0093] After the hydrogen supply electromagnetic valve 24 is opened (Step S223), the set pressure of the hydrogen secondary pressure regulatable pressure valve (variable regulator) 23 is alternately set (established) at either 0.1 MPa or 0.2 MPa every 0.1 seconds (Step S225). Namely, the set pressure is repeatedly changed between 0.1 MPa and 0.2 MPa at intervals of 0.1 seconds. The hydrogen gas pressure supplied to the fuel cell stack 100 pulses in a short time due to this change of setting.

[0094] Since a change in a hydrogen gas stream in the fuel chamber 30 and other passages comes out with this pulsation, occurrence of a stay in the fuel chamber 30 and other passages or occurrence of a portion where the hydrogen gas flow rate is relatively slow is prevented, and the replacement (substitution) from residual gas to hydrogen gas is carried out evenly and quickly.

[0095] Since the operations following Step S225, namely, the operations at Steps S227-S239 are same as those at Steps S125-S137 of the first embodiment shown in Fig. 15, a description of these steps is omitted.

[0096] Next, a description will be given for the structure of the fuel cell system in a third embodiment shown in Fig. 18. Compared with the fuel cell system 1 of the first embodiment, the fuel cell system of the third embodiment further includes a start-up hydrogen discharge line 206 on the upstream side of

the hydrogen pump 25 on the hydrogen outflow line 203.

[0097] On the start-up hydrogen discharge line 206, a hydrogen discharge electromagnetic valve 27b and a silencer 28b are provided in this order. The open/close operation of the hydrogen discharge electromagnetic valve 27b is controlled by a control section (not shown in the drawings) as well as the first embodiment described above.

[0098] Since other elements of the system in the third embodiment are same as those of the system 1 in the first embodiment, a description of these structures is omitted. The start-up operation of the second embodiment is described with reference to Figs. 14 and 15. In this embodiment, the start-up hydrogen discharge electromagnetic valve 27b is open after Step S115 of the first embodiment, and then the operation at Steps S121-S137 is carried out. In this case, since the cross-sectional area of the start-up hydrogen discharge line 206 is formed wider than that of the hydrogen outflow line 203, pressure loss in the start-up hydrogen discharge line 206 hardly occurs at the hydrogen discharge time.

[0099] Next, a description will be given for the structure of the fuel cell system in fourth and fifth embodiments shown in Fig. 19. Compared with the fuel cell system 1 of the first embodiment, the fuel cell system of the fourth and fifth embodiments includes a hydrogen secondary pressure regulating valve 72a in place of the hydrogen secondary pressure regulatable pressure valve 23. The system of the fourth and fifth embodiments further includes a start-up hydrogen secondary pressure regulating valve 72b and a start-up hydrogen supply electromagnetic valve 73 on a line 71. Both ends of the line 71 are respectively connected to the upstream and downstream sides of the hydrogen secondary pressure regulating valve 72a. The set values (both are respectively constant values) of both the hydrogen secondary pressure regulating valve 72a and the start-up hydrogen secondary pressure regulating valve 72b are 0.1 MPa and 0.2 Mpa, respectively. Namely, the set value (pressure) of the hydrogen secondary pressure regulating valve 72a is a hydrogen supply pressure at a

normal operation time, while the set value (pressure) of the start-up hydrogen secondary pressure regulating valve 72b is set (established) at the value higher than the hydrogen supply pressure at the normal operation time. The control section (not shown in the drawings) controls open/close operation of the start-up hydrogen supply electromagnetic valve 73. Since other elements of the system in the fourth and fifth embodiments are same as those of the system 1 in the first embodiment, a description of these structures is omitted.

[0100] In this regard, the control section (not shown in the drawings) controls the open/close of the start-up hydrogen supply electromagnetic valve 73. The hydrogen secondary pressure regulating valve 72a and the start-up hydrogen secondary pressure regulating valve 72b, and the start-up hydrogen supply electromagnetic valve (switching valve) 73 constitute the pressure regulating means in these embodiments. The control section as switching means also controls the pressure regulating means in these embodiments.

[0101] Figs. 20 and 21 is a flowchart illustrating the control operation at the start-up time of the fuel cell system in the fourth embodiment. Since the operations at Steps S301-S319 are same as those at Steps S101-S119 of the first embodiment shown in Fig. 14, a description of these steps is omitted. After the hydrogen pump 25 is switched ON (Step S319), the start-up hydrogen supply electromagnetic valve 73 is opened (Step S321), and the hydrogen supply electromagnetic valve 24 is opened (Step S323). Thus, high-pressured hydrogen gas is supplied from the hydrogen tanks 11 to the fuel cell stack 100 through the start-up hydrogen secondary pressure regulating valve 72b having the high set value. At this time, the hydrogen secondary pressure becomes 0.2 MPa. Since the operations following Step S323, namely, the operations at Steps S325-S333 are same as those at Steps S125-S133 of the first embodiment shown in Fig. 15, a description of these steps is omitted.

[0102] In the case where the hydrogen concentration is more than 95 volume percent, the oxygen concentration is less than 1 volume percent, and all of the local electrical potentials are less than 1.1 V, the start-up hydrogen supply

electromagnetic valve 73 is closed (Step S335). Thus, the supply of the hydrogen gas to the start-up hydrogen supply electromagnetic valve 73 is stopped, while the supply of the hydrogen gas to the hydrogen secondary pressure regulating valve 72a, which is set at the secondary pressure when the fuel cell stack 100 is under the normal power generation state, is started.

[0103] Then, the hydrogen discharge electromagnetic valve 27a is closed (Step S337), and this start-up operation program is terminated and the system proceeds to a normal operation (power generation) routine (this routine is not shown in the flowchart.).

[0104] Next, Figs. 22 and 23 are a flowchart illustrating control operation at the start-up time of the fuel cell system in the fifth embodiment. Since the operations at Steps S401-S419 are same as those at Steps S101-S119 of the first embodiment shown in Fig. 14, a description of these steps is omitted. After the hydrogen pump is switched ON (Step S419), the start-up hydrogen supply electromagnetic valve 73 is opened (Step S421), and the hydrogen supply electromagnetic valve 24 is opened (Step S423).

[0105] After the hydrogen supply electromagnetic valve 24 is opened (Step S423), the start-up hydrogen electromagnetic valve 73 is repeatedly switched open/close every 0.1 seconds (Step S425). When the start-up hydrogen electromagnetic valve 73 is opened, the hydrogen gas is supplied to the fuel cell stack 100 through the start-up hydrogen secondary pressure regulating valve 72b, which is set at the high-pressured side, whereby the hydrogen secondary pressure becomes 0.2 MPa. On the other hand, when start-up hydrogen electromagnetic valve 73 is closed, the hydrogen gas is supplied to the fuel cell stack 100 through the hydrogen secondary pressure regulating valve 72a, which is set at the low-pressure side, whereby the hydrogen secondary pressure becomes 0.1 MPa. In this way, due to this pulsation of the hydrogen pas pressure, occurrence of a stay in the fuel chamber 30 and other passages or occurrence of a portion where the hydrogen gas flow rate is relatively slow is prevented, and the replacement (substitution) from residual gas to hydrogen

gas is carried out more evenly and quickly.

[0106] Since the operations following Step S425, namely, the operations at Steps S427-S439 are same as those at Steps S325-S337 of the fourth embodiment shown in Fig. 21, a description of these steps is omitted.

[0107] As mentioned above, according to the fuel cell system of the present invention, the high-pressured hydrogen gas having a predetermined pressure higher than the pressure in the normal power generation state is supplied to the fuel chamber 30 at the generation start-up time when there is the substituted gas in the fuel chamber 30, whereby the high-pressured hydrogen gas pushes out the stayed substituted gas from the fuel chamber 30. Therefore, since an inside state of the fuel chamber 30 changes from the stagnation state to the flowing state, the occurrence of uneven distribution of the substituted gas and the hydrogen gas is prevented. Further, since the hydrogen gas having the higher pressure than the pressure in the normal power generation state is supplied to the fuel chamber 30 to complete the replacement from the substituted gas to the hydrogen gas at once, the uneven distribution between the substituted gas and the hydrogen gas hardly occurs and there is no time to produce the redox reaction between these gases. Therefore, the occurrence of the local electric current is prevented. In this regard, the completion of replacement from the substituted gas to the hydrogen gas within 0.7 seconds, preferably within 0.5 seconds allows the occurrence of the local electric current due to the gas uneven distribution to be prevented. Further, by shorting the supply time as mentioned above, it is possible to reduce waste of the hydrogen gas.

[0108] Further, by alternately changing the supply pressure of the hydrogen gas as shown in the second and fifth embodiments, the change of the gas stream in the fuel chamber 30 occurs, and this change allows the gas stay (gas stagnation) to be prevented. Therefore, in these embodiments, the uneven distribution of the gas can hardly occur in the fuel chamber 30.

[0109] In this regard, in the present invention, the program of the start-up operation includes, after the step at which the ignition key is turned on, a step at which it may be judged whether or not the ignition key (start switch) is turned on after the lapse of a predetermined period of time, and the program is carried out in the case where the ignition key is turned on after the lapse of the predetermined period of time after the ignition key has been turned off in the normal power generation state.

[0110] As described above, it should be noted that, even though the fuel cell system of the present invention has been described with reference to the preferred embodiments shown in the drawings, the present invention is not limited to these embodiments, it is of course possible to make various modifications to each element of the fuel cell system, and various elements described above can be replaced with any other elements capable of performing the same or a similar function.